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DYNAMIC UNBALANCE DETERMINATION OF SUBMUNITION BOMBLETS.(U)
MAY 79 C C BUSH, C J NIETUBICZ

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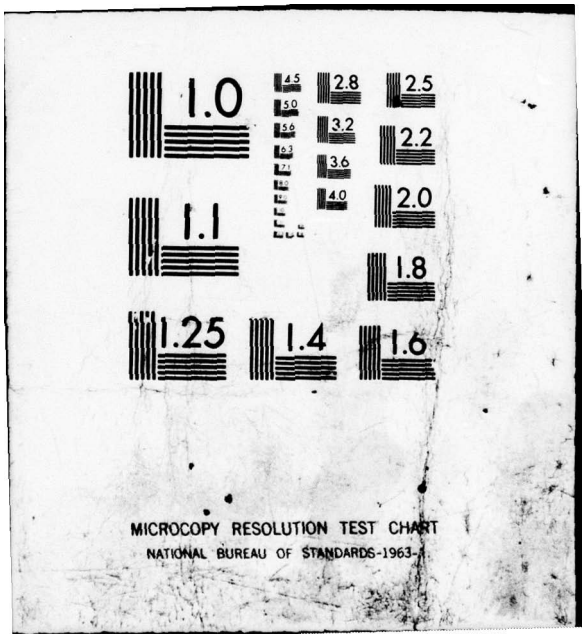
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MEMORANDUM REPORT ARBRL-MR-02923

(Supersedes IMR No. 593)

DYNAMIC UNBALANCE DETERMINATION OF SUBMUNITION BOMBLETS

Clarence C. Bush
Charles J. Nietubicz

May 1979

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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This BRL Memorandum Report supersedes BRL Interim Memorandum Report No. 593 dated March 1978.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Bomblet
Submunitions
Balance
Dispersion

20. ABSTRACT (Continue on reverse side if necessary and identify by block number) (lcb)

An experimental program has been conducted to determine the dynamic unbalance of inert submunition grenades and bomblets. Dynamic unbalance influences the free flight spin-up of these spherical-shaped, vaned bomblets and may cause improper performance of the bomblet fusing process. These bomblets, of known balance characteristics, will be dispersed by missiles and subsequently recovered. An attempt will be made by others to correlate the ground pattern and the armed or non-armed condition of the individual fusing mechanisms with the degree of dynamic unbalance of each bomblet.

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I. INTRODUCTION

The bomblet unbalance data supplied in this report were determined by the Aerodynamics Research Branch, LFD, BRL, for eighty-five XM74 grenades and ninety-five BLU63 bomblets at the request of the Fluid Mechanics Branch, Applied Sciences Division, LCWSL, ARRADCOM, Dover, New Jersey.

A brief discussion is presented here as an aid to understanding the tabulated data, the methods for obtaining the data, and the accuracy of those determinations.

Measurements of axial and transverse moments of inertia, center of gravity locations, weights and polar diameters were supplied by the Fluid Mechanics Branch for use, in conjunction with the BRL measured mass unbalances, in the computation of the angle of unbalance of each bomblet (the angle formed by the geometric spin axis and the dynamic axis).

II. DATA ACQUISITION

Both types of bomblets have identical exterior size and shape, within manufacturing tolerances. Thus, a single fixture and model-holding adapter could be used during the unbalance measurements. The canister type adapter, shown in Figure 1, was designed and fabricated at the BRL. The adapter made use of a contoured inner surface, formed by a plastic molding process, to provide reproducibility of model positioning and the alignment of the model spin about its geometric axis.

Dynamic unbalance measurements were made on the empty fixture prior to the model's being installed; then these tare values were vectorially subtracted from the balancing measurements made with the bomblets in the fixture. Balancing data are given in gram-inches at two preselected measurement stations. The left measurement plane was established at the left end of the canister and the right measurement plane at the right end of the canister (refer to Figures 1 and 2).

A Balance Technology, Inc., Model D-75PS dynamic balancing machine was used for measuring the bomblet unbalances. This machine is specified as being capable of detecting peak-to-peak vibrations of .000025 inch for standard operation; a peak-to-peak displacement of .000025 inch represents a measurement of 0.1135 gram-inch (.004 ounce-inch) on a ten pound rotating mass. (The weight of the complete rotating assembly, including bomblet, used in these unbalance measurements was approximately five pounds. Thus, without consideration for the cantilever arrangement and unusually close-coupled measurement planes, the machine was capable of resolving unbalances of approximately 0.05 gram-inch during these bomblet unbalance measurements.)

obtain values for the products of inertia in that system. From the resulting inertia tensor, we could compute the three real eigenvalues I1, I2, I3 and the directions of the three eigenvectors. Then in a coordinate system X1, X2, X3 whose axes have the directions of these eigenvectors, the products of inertia vanish and the principal moments of inertia are I1, I2, I3. The angle of unbalance α is, then, the angle between the x and X1 axes.

For lack of time, we performed an eigenanalysis only on a representative set of grenades and bomblets (Table I, column 14). Approximate values of α from Equation (1), however, were obtained for all the grenades and bomblets (Table I, column 13). For each eigenanalysis value of α, we computed a correction factor

$$\Delta = \alpha_e - \alpha_a \tag{2}$$

where subscript "e" denotes an exact (eigenanalysis) value and subscript "a" denotes the approximate value from Equation (1). Figure 3 is a plot of Δ versus α_a up to 34 degrees; the curve shown is a fairing through the plotted points. From this faired curve, we read a Δ value for each grenade and bomblet omitted from the eigenanalysis (Table I, column 15). Finally, we obtained corrected values of the angle of unbalance (Table I, column 16) by the relation

$$\alpha = \alpha_a + \Delta \tag{3}$$

IV. EXPERIMENTAL RESULTS

Table I presents the unbalance measurements made by BRL, the physical data supplied by the Fluid Mechanics Branch, the computed center of gravity offset, and the computed angle of unbalance for all 180 bomblets. The individual bomblets are identified by the Fluid Mechanics Branch code number listed in the initial column. These final results are summarized in histogram form in Figures 4 and 5.

V. DISCUSSION OF POSSIBLE ERROR

On page 8 it was indicated that the individual unbalances at the two planes of measurement were reproducible to within 0.3 gram-inch and their related angles to within ± 8 degrees. The accuracy of these values depends on the fixture calibrations. When a four gram mass of modeling clay was attached to the bomblet canister at the left measurement plane, a 3.75 gram dynamic unbalance resulted at the left plane indicator, and when a four gram mass of clay was added to the canister at the right measurement plane, a 3.95 gram dynamic unbalance resulted

at the right plane indicator. The precision fixture for unbalance calibrations was not used for this experiment because it does not represent a good replication of the actual geometry. As was expected, these results are only qualitative but do determine the location of the decimal point in the unbalance indicators.

For four independently repeated measurements on "control" grenade PA90A, the final angle of unbalance ranged from 7.1 to 8.2 degrees. This implies a ± 7.8% range of measurement error from the mean measured value. Eleven independent balance measurements on "control" bomblet PA671 indicated from 8.8 to 11.0 degrees for the final angle of unbalance and that result equates to a ± 11.1% range of measurement error from the mean measured value.

It is difficult to analyze the total possible error inherent in the complete measurement and computation procedure. In view of this difficulty, the Fluid Mechanics Branch, ASD, requested from LFD an alternative procedure for error investigation. This procedure employed trial computations with a 1% deviation in the input parameters to determine their individual effect on the final angles of unbalance. The result of this exercise determined the relative importance of each parameter in the final result. These data, presented in Table II, show that utmost accuracy is required in the moment of inertia measurements.

VI. CONCLUSIONS

A. Repeated measurements of the angle of unbalance of XM74 grenades and BLU63 bomblets indicate that these measurements are routinely reproducible to approximately ± 1 degree when care is taken to avoid all possible errors from machine drift, etc. This value of ± 1 degree allows for the imperfect repeatability of the bomblet position in the holding fixture, but does not allow for measurement inaccuracies in such things as the bomblet moments of inertia, weight, diameter and C.G. distance. Also, it assumes absolute performance accuracy from the balancing machine and from the data reduction computations. The error possibilities in the input parameters can be expected to have a degrading effect on the overall measurement and computation accuracy. Therefore, the overall error possibility is larger than the ± 1 degree measurement reproducibility but is estimated to be less than ± 2 degrees.

B. An intentional 1% deviation in the moment of inertia input can result in deviations of ± 5 degrees or more in the computed angle of unbalance. This indicates a need for utmost precision in acquiring those measurements. The bomblet diameter, C.G. distance, and unbalance measurements are less critical, but can also produce significant error.

ACKNOWLEDGEMENTS

The authors are indebted to Dr. Andrew Mark for his capable aid in gaining an understanding of the problem and the procedures required, to William Beims and James Harmon for their assistance in making the unbalance measurements, and to Raymond Lehman and Donald Mylin for their aid in the data reduction.

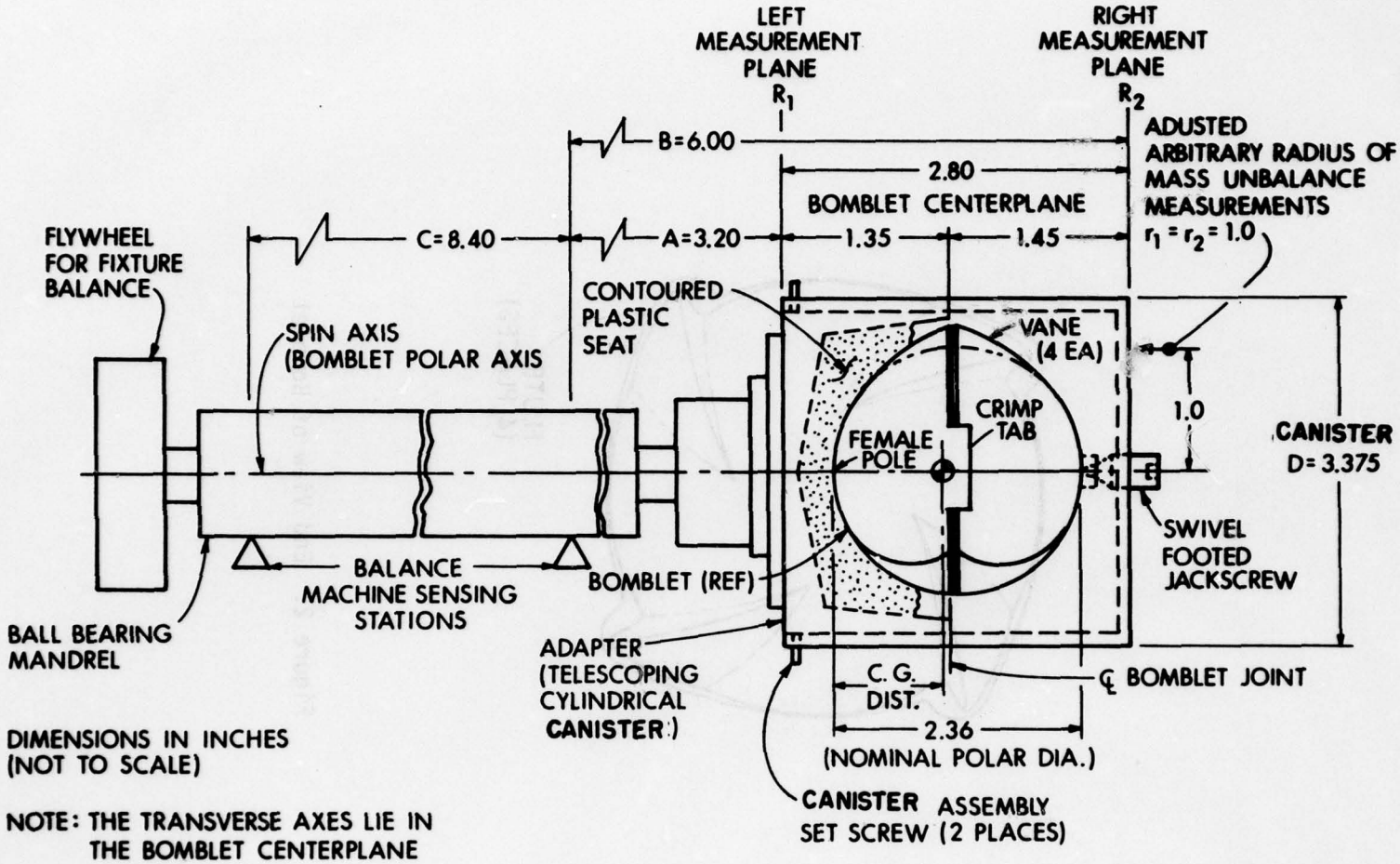

Figure 1. Balancing Geometry

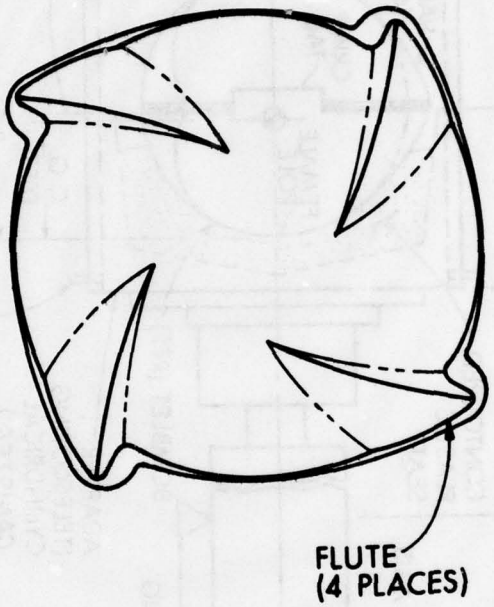

Figure 2. End View of Bomblet

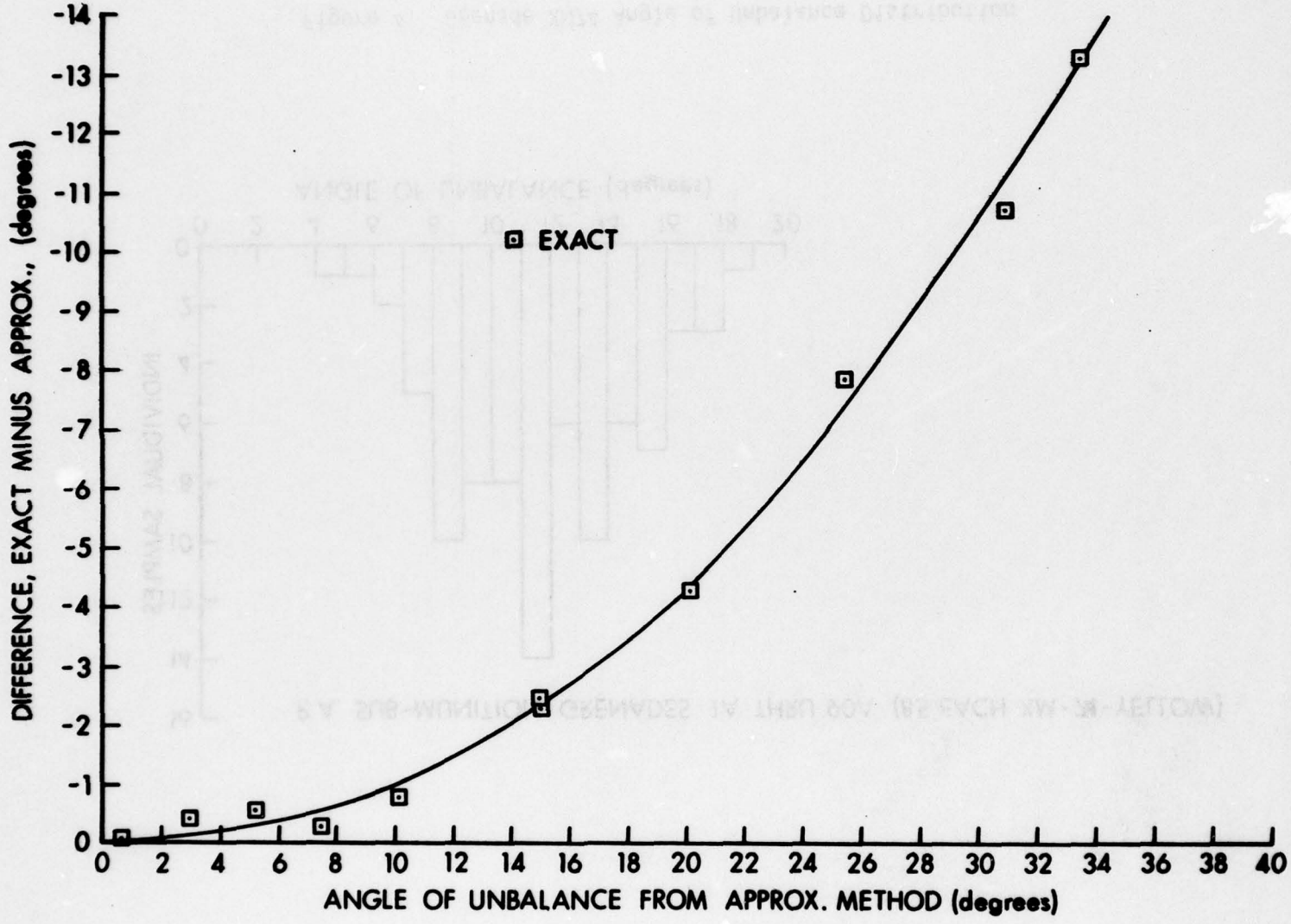

Figure 3. Procedure Correlation Graph

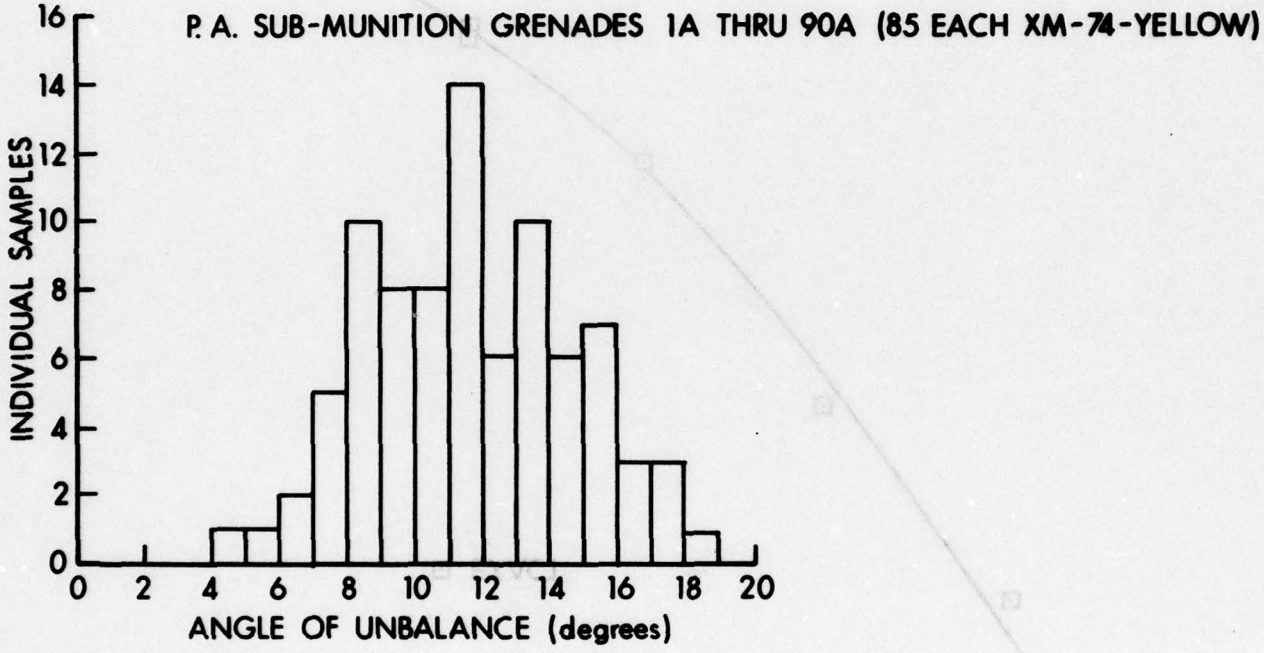

Figure 4. Grenade XM74 Angle of Unbalance Distribution

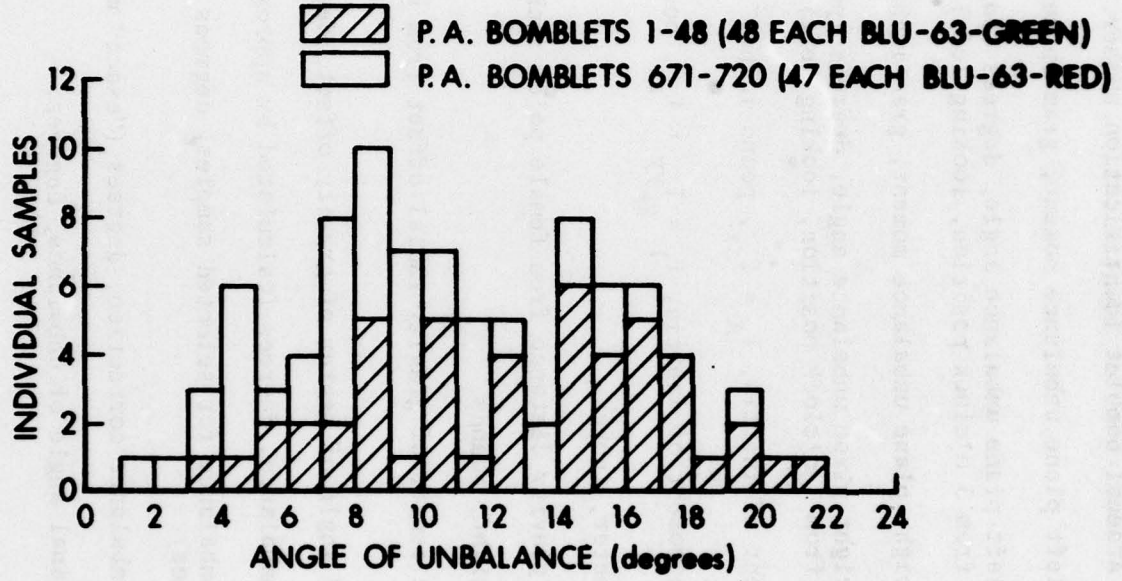

Figure 5. Bomblet BLU 63 Angle of Unbalance Distribution

Table I. Experimental Results

Column Headings for Table I.

1. Picatinny Arsenal bomblet identification number.
2. Measured left plane unbalance moment, gram-inches.
3. Measured left plane unbalance angle, degrees (positive, counter-clockwise from 3 o'clock position, looking left).
4. Measured right plane unbalance moment, gram-inches.
5. Measured right plane unbalance angle, degrees (positive, counter-clockwise from 3 o'clock position, looking left).
6. Axial moment of inertia, $I_A = I_{xx}$, pound inches^2.
7. Transverse moment of inertia, $I_T = I_{yy} = I_{zz}$, pound inches^2.
8. Polar diameter, inches.
9. Center of gravity distance from female pole, inches.
10. Bomblet weight, pounds.
11. Calculated center of gravity radial offset from polar axis, inches.
12. Calculated angle of center of gravity offset, degrees.
13. Angle of unbalance, degrees (calculated by approximate method).
14. Angle of unbalance for selected samples, degrees (calculated by exact method).
15. Angle of unbalance correction, degrees ("exact" minus approximate).
16. Adjusted final angle of unbalance, degrees.

Table I. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
							XM-74 YELLOW								
FT	.8760	36.0	1.0200	290.0											
1A	.2465	351.5	2.5245	305.0	.951	.917	2.350	1.195	1.255	.0031	29.0	8.91		-.75	8.16
2A	2.2780	7.5	5.6950	326.0	.961	.925	2.347	1.179	1.270	.0111	104.4	19.46		-4.00	15.46
3A	1.4790	13.0	4.4880	335.0	.974	.938	2.349	1.185	1.283	.0079	90.2	16.70		-2.85	13.85
4A	1.0112	11.5	2.7115	329.5	.970	.933	2.349	1.180	1.281	.0041	59.9	8.65		-.80	7.85
5A	1.9635	15.5	4.3520	316.0	.953	.916	2.346	1.178	1.259	.0078	117.9	13.65		-1.95	11.70
FT	.7820	40.0	.9775	279.5											
6A	2.0995	13.0	4.3690	337.5	.961	.920	2.350	1.185	1.264	.0094	96.7	11.88		-1.20	10.68
7A	1.5640	22.5	3.6465	328.5	.964	.922	2.347	1.188	1.269	.0068	109.0	10.51		-1.10	9.41
8A	1.7935	15.5	4.1310	344.5	.961	.922	2.347	1.179	1.263	.0086	90.7	13.41		-1.80	11.61
9A	1.6575	357.5	4.8450	310.5	.971	.930	2.350	1.180	1.276	.0090	100.6	13.67		-1.90	11.77
10A	2.1250	15.0	3.2725	352.5	.971	.934	2.347	1.179	1.280	.0079	84.5	8.96		-.80	8.16
FT	.8500	38.0	.9350	287.0											
11A	1.6745	359.5	5.2700	335.5	.968	.928	2.346	1.173	1.273	.0101	80.1	17.97		-3.35	14.62
12A	1.6575	.5	5.6100	322.0	.970	.930	2.350	1.190	1.274	.0104	93.6	18.59		-3.60	14.99
13A	1.5555	28.5	3.8845	349.5	.961	.926	2.347	1.179	1.269	.0074	102.0	15.88		-2.65	13.23
14A	1.5385	6.5	3.0600	307.0	.964	.930	2.348	1.174	1.271	.0053	105.9	7.89		-.60	7.29
15A	1.3770	10.0	4.0375	329.0	.965	.927	2.349	1.180	1.271	.0072	88.3	13.48		-1.80	11.68
FT	.8585	41.0	.9605	279.5											
16A	1.6575	19.0	3.6125	311.0	.962	.924	2.349	1.180	1.268	.0063	118.5	10.90		-1.25	9.65
17A	2.0995	19.0	4.7600	335.0	.971	.933	2.349	1.180	1.278	.0096	104.9	15.82		-2.60	13.22
18A	1.9210	8.0	4.9300	339.0	.965	.930	2.352	1.176	1.273	.0101	87.8	18.67		-3.65	15.02
19A	1.8020	7.0	4.1480	329.5	.973	.935	2.347	1.184	1.284	.0082	91.5	12.24		-1.50	10.74
20A	1.9550	7.0	3.7825	329.0	.969	.933	2.353	1.181	1.277	.0079	92.7	10.36		-1.00	9.36
FT	.8500	37.5	1.0115	281.0											
21A	1.7850	14.0	2.6180	342.0	.962	.926	2.349	1.180	1.269	.0058	83.7	6.81		-.45	6.36
22A	2.0400	358.5	5.5675	321.0	.984	.945	2.351	1.185	1.301	.0107	96.6	17.16		-3.05	14.11
25A	1.3770	8.0	3.9525	333.5	.968	.928	2.348	1.179	1.274	.0072	79.9	12.93		-1.70	11.23
26A	1.6150	11.5	4.8790	326.0	.963	.920	2.351	1.171	1.263	.0090	99.9	15.18		-2.40	12.78
27A	2.2780	18.0	4.9810	335.5	.962	.925	2.351	1.181	1.268	.0103	105.8	16.67		-2.85	13.82
FT	.8585	43.0	.9945	293.5											
28A	2.3460	8.0	4.7090	353.0	.969	.929	2.348	1.174	1.276	.0103	80.6	13.09		-1.70	11.39
29A	2.0655	.5	5.8650	340.5	.969	.930	2.349	1.190	1.277	.0117	82.3	19.01		-3.80	15.21
30A	1.7340	11.0	5.0150	330.5	.965	.926	2.348	1.174	1.275	.0093	96.4	16.09		-2.70	13.39
31A	1.8360	10.5	3.9100	315.0	.974	.938	2.350	1.180	1.284	.0071	108.7	10.65		-1.10	9.55
32A	1.5300	13.0	4.4965	340.5	.966	.924	2.347	1.174	1.271	.0083	84.4	13.87		-2.00	11.87
FT	.8585	47.0	1.1050	298.5											
33A	1.8530	6.5	5.5250	337.5	.972	.937	2.351	1.178	1.281	.0104	86.6	19.74		-4.10	15.64
34A	2.1080	346.0	6.8000	310.0	.958	.920	2.349	1.175	1.260	.0132	97.5	21.36		-4.90	16.46
35A	1.7935	5.5	4.2075	316.5	.962	.923	2.350	1.180	1.265	.0077	101.8	9.78		-.95	8.83
36A	1.4535	1.5	3.6295	340.5	.961	.918	2.348	1.184	1.263	.0067	68.2	9.03		-.80	8.23
FT	.8415	51.0	1.0285	304.0											
37A	1.4960	359.0	3.9100	318.0	.972	.931	2.347	1.186	1.280	.0071	91.4	8.10		-.60	7.50
38A	1.1135	353.5	3.8590	305.5	.968	.926	2.352	1.179	1.269	.0066	90.3	8.50		-.75	7.75
39A	1.7340	5.5	5.2700	321.0	.956	.912	2.347	1.174	1.257	.0098	99.9	13.54		-1.80	11.74
40A	1.9890	.0	4.9980	327.0	.972	.933	2.349	1.182	1.282	.0097	92.3	12.39		-1.50	10.89
41A	1.9890	357.0	5.1340	330.0	.978	.939	2.347	1.181	1.289	.0100	87.4	13.03		-1.70	11.33
FT	.7565	46.0	.9265	296.0											
42A	1.9550	357.0	5.6100	325.5	.967	.927	2.348	1.179	1.275	.0110	93.5	16.20		-2.70	13.50
43A	1.5640	7.0	5.9500	320.0	.980	.941	2.347	1.181	1.293	.0105	103.9	21.29		-4.80	16.49
44A	1.1560	11.0	3.7740	315.0	.968	.929	2.348	1.174	1.275	.0062	99.0	11.01		-1.20	9.81
45A	1.4110	358.5	4.9300	328.5	.971	.929	2.345	1.167	1.283	.0090	83.1	14.71		-2.20	12.51
46A	1.8105	8.5	5.1170	324.0	.965	.924	2.345	1.175	1.271	.0097	103.8	14.89	12.44	.00	12.44
FT	.8415	32.0	.8925	271.0											
47A	1.9125	22.0	6.1200	344.5	.967	.926	2.347	1.179	1.271	.0121	108.2	25.40	17.56	.00	17.56
48A	2.1505	358.5	5.9500	331.0	.964	.922	2.345	1.183	1.269	.0123	91.4	19.26		-3.90	15.36

Table I. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
49A	1.8445	10.0	4.8875	322.0	.968	.924	2.346	1.181	1.273	.0094	107.9	14.89		-2.30	12.59
50A	1.8870	353.0	5.2700	325.5	.962	.926	2.348	1.172	1.269	.0107	86.5	19.68		-4.05	15.63
51A	1.9465	24.0	3.3660	326.5	.967	.931	2.351	1.179	1.274	.0068	117.1	11.53		-2.30	9.23
FT	.8670	44.0	1.0370	298.0											
52A	1.5385	13.0	5.1000	338.0	.967	.927	2.351	1.181	1.272	.0091	87.4	16.95		-3.00	13.95
53A	2.0400	18.0	3.7315	335.0	.969	.933	2.351	1.173	1.276	.0074	99.8	9.39		-.80	8.59
54A	1.9040	6.5	3.4510	331.0	.971	.933	2.350	1.173	1.278	.0068	89.8	6.88		-.45	6.43
55A	1.2920	9.0	3.5020	334.0	.965	.923	2.344	1.185	1.274	.0060	75.6	9.03		-.80	8.23
56A	1.3005	23.5	3.1110	332.5	.974	.933	2.347	1.174	1.282	.0050	93.6	8.14		-.60	7.54
FT	.7480	32.5	.8670	267.0											
57A	1.9720	7.5	5.2275	329.0	.978	.939	2.347	1.179	1.290	.0106	102.5	18.06		-3.40	14.66
58A	1.6830	25.5	4.4880	330.0	.979	.939	2.349	1.180	1.291	.0085	121.0	16.62		-2.85	13.77
59A	1.9635	11.0	4.2330	329.0	.971	.931	2.346	1.181	1.278	.0089	103.8	12.65		-1.55	11.10
60A	2.0060	14.5	4.2160	334.0	.962	.919	2.349	1.175	1.264	.0091	103.8	12.01		-1.40	10.61
61A	1.5470	6.0	4.1650	332.5	.971	.934	2.356	1.173	1.280	.0083	91.4	15.25		-2.40	12.85
FT	.8075	34.5	.8840	270.0											
62A	2.3290	5.5	4.4540	324.5	.966	.924	2.347	1.174	1.271	.0098	102.1	11.46		-1.30	10.16
63A	1.5130	22.5	4.8705	348.0	.958	.919	2.346	1.176	1.265	.0096	99.5	20.98		-4.75	16.23
64A	2.5840	15.5	5.1000	341.0	.962	.926	2.345	1.171	1.274	.0115	102.0	17.84		-3.35	14.49
65A	2.0315	4.5	5.0150	326.0	.979	.940	2.348	1.177	1.288	.0102	99.5	16.45		-2.80	13.65
66A	1.7255	14.0	5.3550	334.0	.975	.934	2.347	1.174	1.288	.0103	102.2	20.02	15.64	.00	15.64
FT	.7905	34.0	.9435	270.0											
67A	1.8615	359.0	6.1200	330.5	.971	.934	2.352	1.184	1.276	.0121	89.8	25.28		-7.25	18.03
68A	1.2750	22.0	1.5130	350.0	.957	.917	2.346	1.171	1.259	.0037	74.3	5.50		-.30	5.20
69A	2.3630	15.5	5.1000	335.0	.962	.920	2.345	1.170	1.263	.0110	106.0	15.68		-2.55	13.13
70A	2.0230	33.0	3.4765	355.0	.981	.944	2.346	1.176	1.300	.0080	106.3	12.71		-1.65	11.06
72A	2.0910	19.5	4.0970	340.0	.967	.923	2.347	1.181	1.271	.0090	103.2	11.50		-1.35	10.15
FT	.8160	36.5	.9350	266.5											
73A	1.9210	27.5	3.3490	328.0	.962	.920	2.348	1.181	1.264	.0069	117.3	10.04		-1.00	9.04
76A	1.8955	5.5	3.9610	319.0	.961	.926	2.349	1.175	1.268	.0082	100.9	12.78		-1.60	11.18
77A	2.1335	15.0	3.9950	355.5	.977	.937	2.348	1.175	1.289	.0094	85.5	13.21		-1.80	11.41
78A	1.3260	12.5	3.2300	329.0	.973	.938	2.349	1.170	1.286	.0061	87.8	12.47		-1.50	10.97
79A	1.6405	349.0	5.1000	331.0	.954	.914	2.342	1.179	1.257	.0104	73.2	18.03		-3.40	14.63
FT	.8075	34.5	.9520	269.0											
80A	1.7000	.0	5.4825	338.0	.970	.935	2.352	1.184	1.278	.0109	80.4	24.70		-6.80	17.90
81A	2.1335	6.5	5.9500	334.0	.968	.932	2.349	1.180	1.277	.0122	96.9	24.42		-6.70	17.72
82A	1.7170	20.0	3.7230	326.0	.963	.922	2.345	1.168	1.266	.0073	111.7	11.77		-1.35	10.42
83A	2.0995	10.5	4.8450	315.0	.970	.929	2.348	1.182	1.275	.0095	114.7	14.92		-2.30	12.62
84A	1.8445	15.5	3.3490	325.0	.977	.936	2.350	1.180	1.283	.0068	105.4	9.00		-.80	8.20
FT	.8925	34.0	.9265	267.0											
85A	1.9125	358.0	3.8165	321.0	.964	.924	2.349	1.184	1.271	.0081	90.2	9.88		-.95	8.93
86A	1.5300	24.5	1.7935	332.0	.959	.917	2.345	1.180	1.265	.0040	96.3	4.44		-.20	4.24
87A	1.7765	6.5	4.2160	335.5	.969	.928	2.349	1.177	1.274	.0087	86.7	13.81		-1.90	11.91
88A	2.3035	13.0	3.8420	344.0	.970	.927	2.350	1.182	1.277	.0091	92.8	10.09		-1.00	9.09
89A	1.2410	2.0	2.7030	326.0	.955	.920	2.349	1.175	1.258	.0052	68.2	9.76		-.90	8.86
90A	1.6065	17.5	2.6435	353.0	.962	.920	2.346	1.173	1.266	.0061	79.2	9.00		-.80	8.20

Table I. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
							GREEN ALU-63								
FT	.8245	50.0	1.1220	308.0											
1	1.6915	21.0	2.9410	350.0	.650	.623	2.354	1.167	.914	.0079	82.5	9.06		-.80	8.26
2	.8330	15.0	.3910	307.5	.651	.627	2.353	1.182	.920	.0006	255.0	9.27		-.85	8.42
3	1.2155	33.0	3.5105	15.5	.669	.644	2.360	1.190	.934	.0087	63.3	23.31		-6.00	17.31
4	1.9805	19.0	4.0800	350.0	.661	.641	2.366	1.183	.929	.0111	88.2	20.88		-4.70	16.18
5	1.4110	30.0	3.1195	7.5	.654	.634	2.360	1.180	.922	.0081	72.3	21.60		-5.00	16.60
6	1.0030	40.0	2.2525	316.5	.660	.638	2.359	1.180	.927	.0032	122.1	8.36		-.65	7.71
7	1.0965	35.5	3.0345	15.0	.650	.625	2.350	1.170	.917	.0074	58.1	20.24		-4.40	15.84
8	1.4195	33.0	1.0540	349.0	.655	.633	2.362	1.181	.923	.0031	62.7	5.44	5.14	-.30	5.14
9	1.2155	30.0	3.2045	359.0	.651	.627	2.357	1.179	.917	.0076	72.5	17.91		-3.35	14.56
10	1.5980	31.5	2.4735	283.0	.653	.628	2.355	1.178	.920	.0036	165.9	14.80		-2.30	12.50
11	1.7255	14.5	3.4170	347.0	.661	.636	2.361	1.181	.930	.0090	81.3	12.11		-1.45	10.66
12	1.1220	36.0	2.9155	48.5	.659	.637	2.361	1.181	.925	.0083	31.8	33.51	20.28	.00	20.28
13	1.5300	14.0	3.1515	331.0	.656	.634	2.362	1.186	.923	.0075	91.4	10.51		-1.05	9.46
14	1.6405	35.5	3.5700	13.0	.665	.641	2.363	1.187	.933	.0097	82.5	20.37		-4.40	15.97
15	1.2665	26.0	1.7255	354.0	.658	.637	2.359	1.180	.925	.0042	61.8	7.95		-.60	7.35
FT	.7905	42.5	.8925	283.5											
16	1.4025	37.0	3.6465	19.5	.657	.634	2.354	1.177	.923	.0107	87.5	32.63		-12.70	19.93
FT	.8755	39.0	1.0710	292.0											
17	1.1050	8.5	3.2060	272.5	.660	.635	2.363	1.184	.926	.0062	133.4	14.99	12.76	.00	12.76
18	1.3090	15.5	3.3915	353.0	.655	.629	2.356	1.171	.919	.0086	64.8	19.50		-4.00	15.50
19	1.2495	39.5	3.0430	20.0	.655	.631	2.359	1.175	.921	.0085	90.6	24.74		-6.85	17.89
20	.9010	356.0	2.9155	292.5	.658	.633	2.353	1.179	.922	.0060	87.6	9.21		-.80	8.41
FT	.8245	33.5	.8925	275.5											
21	.6970	37.5	2.4565	50.0	.660	.635	2.359	1.182	.924	.0073	219.3	27.82		-8.95	18.87
22	1.1135	44.0	1.0540	340.0	.653	.628	2.364	1.180	.918	.0032	120.7	6.16		-.40	5.76
23	1.7680	24.5	1.8190	357.5	.653	.626	2.363	1.184	.917	.0069	84.5	7.04		-.50	6.54
24	1.2240	33.5	2.8730	338.5	.657	.632	2.356	1.178	.923	.0070	122.4	18.08		-3.40	14.68
25	1.4450	26.0	2.9665	319.5	.636	.603	2.363	1.167	.900	.0071	123.4	11.59		-1.40	10.19
FT	.7990	44.0	.9860	295.5											
26	1.3770	31.0	1.8020	341.0	.656	.631	2.353	1.174	.923	.0046	90.6	5.43		-.30	5.13
27	1.0880	30.0	.6290	235.5	.657	.634	2.370	1.175	.924	.0013	309.4	9.65		-.90	8.75
28	1.2325	31.0	.4760	275.0	.651	.626	2.355	1.175	.916	.0012	20.7	6.65		-.45	6.20
29	1.5640	36.0	3.7655	355.5	.648	.623	2.355	1.170	.911	.0100	104.4	22.04		-5.30	16.74
30	1.3685	34.0	3.2215	332.0	.652	.629	2.355	1.183	.918	.0072	118.5	17.43		-3.15	14.28
31	1.4960	27.0	3.2300	357.5	.652	.628	2.363	1.177	.916	.0088	85.5	17.95		-3.35	14.60
FT	.8245	40.0	.9945	289.0											
32	1.3855	21.0	1.5130	344.5	.660	.634	2.358	1.177	.924	.0044	71.5	5.46		-.30	5.16
33	1.5555	33.0	3.6550	334.0	.656	.631	2.364	1.182	.920	.0087	120.7	20.09		-4.30	15.79
34	1.4025	32.0	3.9355	358.0	.657	.634	2.360	1.182	.923	.0102	97.2	30.44	19.75	.00	19.75
35	1.6235	24.5	3.5020	354.0	.651	.625	2.354	1.167	.917	.0098	89.5	18.44		-3.60	14.84
36	1.3770	35.5	3.3490	5.5	.658	.632	2.363	1.182	.923	.0091	95.2	21.23		-4.90	16.33
FT	.7905	42.5	.8925	283.5											
37	1.2580	52.0	1.3940	20.0	.655	.629	2.355	1.173	.921	.0053	102.9	9.39		-.90	8.49
38	1.5045	22.5	1.2665	344.5	.654	.628	2.371	1.188	.917	.0046	75.5	3.91		-.20	3.71
39	1.5470	27.0	3.0260	322.0	.654	.629	2.367	1.181	.919	.0074	117.5	14.08		-2.00	12.08
40	1.5470	38.0	3.2385	21.0	.653	.627	2.366	1.181	.918	.0102	88.0	21.44		-4.50	16.94
FT	.8840	36.0	.7055	268.5											
41	.9265	44.5	1.0030	66.5	.655	.631	2.368	1.184	.921	.0043	124.4	12.41		-1.50	10.91
42	1.1900	16.0	3.3320	352.0	.656	.631	2.365	1.175	.921	.0090	65.2	24.69		-6.85	17.84
43	.6120	33.0	2.7880	268.5	.658	.631	2.357	1.176	.924	.0054	49.1	13.50		-1.90	11.60
44	1.2325	38.5	1.9125	322.5	.655	.632	2.355	1.175	.922	.0043	141.6	12.13		-1.45	10.68
45	1.7765	22.0	4.4540	344.0	.657	.635	2.361	1.176	.924	.0000	.0	.00	21.80	.00	21.80
46	1.3770	40.0	2.9070	5.5	.651	.627	2.363	1.182	.915	.0085	114.6	22.70		-5.65	17.05
47	1.7000	36.0	2.6860	21.0	.654	.630	2.358	1.177	.920	.0092	92.0	18.64		-3.90	14.74
48	1.6660	31.5	2.4565	320.0	.655	.632	2.363	1.182	.921	.0064	127.8	14.35		-2.10	12.25

Table I. Concluded

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
							RED BLU-63								
FT	.8495	40.0	.9520	288.0											
671	1.3685	23.0	2.4055	297.5	.656	.632	2.356	1.178	.924	.0045	130.2	9.70		-.90	8.80
673	1.2155	33.5	1.7850	346.0	.655	.629	2.359	1.180	.922	.0046	90.9	8.21		-.70	7.51
674	1.6150	35.0	2.5585	10.0	.655	.626	2.360	1.180	.920	.0081	88.7	12.22		-1.50	10.72
675	1.6150	15.0	2.4985	343.5	.651	.628	2.366	1.188	.918	.0072	80.9	10.34		-1.05	9.29
677	1.4025	27.0	3.1785	352.0	.652	.625	2.359	1.170	.917	.0084	89.8	16.79		-2.95	13.84
678	1.1980	26.5	2.4565	1.0	.655	.631	2.361	1.180	.922	.0066	68.7	16.22		-2.75	13.47
679	1.5555	51.0	1.4875	70.0	.657	.633	2.357	1.179	.926	.0072	73.9	13.32		-1.80	11.52
681	1.4705	22.0	2.0825	352.5	.655	.631	2.358	1.179	.922	.0061	76.3	9.85		-.90	8.95
682	.8245	22.5	1.2495	335.0	.657	.634	2.358	1.179	.924	.0023	18.4	7.54	7.33	.00	7.33
683	.9350	31.0	1.7080	291.0	.652	.626	2.350	1.178	.918	.0021	126.8	4.61		-.30	4.31
684	1.1560	23.0	3.2895	292.5	.652	.628	2.360	1.190	.918	.0063	136.1	17.12		-3.05	14.07
685	1.4365	22.0	3.1450	312.0	.651	.627	2.366	1.183	.917	.0069	119.6	14.74		-2.25	12.49
686	1.0540	23.5	1.8445	350.0	.653	.629	2.361	1.176	.919	.0046	55.3	11.06		-1.20	9.86
687	1.8150	41.0	2.1675	26.5	.656	.633	2.359	1.190	.925	.0083	85.1	12.95		-1.75	11.20
688	1.2495	39.0	2.0145	306.5	.649	.623	2.348	1.174	.914	.0032	147.8	7.97		-.70	7.27
FT	.7820	37.0	.8670	280.5											
689	1.3515	32.0	2.4820	10.0	.667	.646	2.366	1.183	.933	.0076	86.6	19.72		-4.05	15.67
690	1.2665	24.5	2.4225	353.5	.655	.629	2.369	1.175	.919	.0068	83.1	13.56		-1.85	11.71
691	1.1475	35.5	1.0285	359.0	.662	.640	2.365	1.183	.929	.0037	81.2	7.35		-.50	6.85
692	1.5385	15.5	3.8335	205.5	.655	.631	2.353	1.172	.921	.0000	.0	.00		.00	23.45
693	1.0795	24.5	2.4990	290.0	.660	.634	2.360	1.178	.926	.0044	141.6	10.98		-1.20	9.78
FT	.8925	41.5	1.1050	290.0											
694	1.1305	33.5	1.2920	268.5	.654	.631	2.368	1.182	.919	.0006	218.7	5.81		-.35	5.46
695	1.6235	24.5	5.8650	347.5	.659	.635	2.361	1.186	.926	.0000	.0	.00		.00	25.19
696	1.1050	32.5	.8585	267.5	.654	.627	2.354	1.177	.920	.0006	320.8	4.66		-.25	4.41
697	1.1390	41.0	1.3600	315.0	.651	.625	2.358	1.179	.916	.0019	112.5	2.90	2.42	.00	2.42
698	1.8275	28.0	5.1595	356.0	.655	.631	2.359	1.182	.923	.0000	.0	.00		.00	23.35
FT	.8415	48.0	1.0540	304.0											
699	.8755	26.5	2.4140	289.0	.659	.635	2.353	1.172	.927	.0040	119.0	9.28		-.85	8.43
700	.8500	51.5	1.0455	36.0	.650	.624	2.356	1.178	.916	.0037	138.7	10.67		-1.10	9.57
701	1.0965	33.5	2.5075	298.0	.664	.639	2.356	1.176	.929	.0039	142.1	10.89	9.32	.00	9.32
702	1.0285	26.5	.4080	27.0	.654	.629	2.353	1.182	.920	.0022	343.4	9.97		-1.00	8.97
703	1.2665	26.5	1.2920	341.0	.656	.630	2.365	1.183	.922	.0030	65.9	3.67		-.20	3.47
FT	.7905	40.5	.6120	270.0											
704	1.2155	35.5	.5015	126.5	.660	.634	2.358	1.174	.927	.0029	30.6	7.61		-.55	7.06
705	1.0880	34.0	1.6660	329.0	.661	.638	2.372	1.184	.927	.0041	112.5	9.73		-.90	8.83
706	1.3260	32.0	1.9380	292.0	.658	.633	2.367	1.184	.922	.0038	148.4	10.34		-1.00	9.34
707	1.7000	16.0	3.7825	349.0	.656	.630	2.362	1.179	.921	.0114	89.4	21.36		-4.95	16.41
708	1.3430	38.0	.7565	22.0	.655	.630	2.367	1.181	.921	.0040	78.2	4.91		-.25	4.66
FT	.7565	40.5	.6290	272.5											
709	1.5980	40.5	1.2155	.0	.657	.632	2.357	1.181	.924	.0052	97.8	4.42		-.20	4.22
710	1.3430	45.0	1.9550	44.0	.652	.626	2.351	1.168	.918	.0072	86.4	13.81		-1.90	11.91
711	1.3515	34.0	1.1730	315.5	.652	.625	2.356	1.183	.917	.0033	112.9	3.61		-.15	3.46
712	2.1675	25.5	4.6920	350.0	.656	.631	2.354	1.177	.921	.0143	105.3	29.63		-10.30	19.33
713	1.3770	39.0	.7395	334.5	.661	.635	2.352	1.174	.925	.0032	96.0	1.30		-.05	1.25
714	1.7000	30.0	2.9665	315.5	.653	.629	2.359	1.177	.919	.0076	131.9	17.80		-3.30	14.50
FT	.9775	44.5	.8160	287.5											
715	1.7170	24.0	1.9890	354.5	.657	.631	2.357	1.179	.921	.0064	77.9	7.75		-.60	7.15
716	1.4450	31.5	1.9890	307.0	.653	.626	2.360	1.188	.919	.0040	123.9	6.70		-.45	6.25
717	1.2495	55.0	.6970	133.5	.654	.627	2.348	1.164	.918	.0042	63.2	8.49		-.70	7.79
718	1.4280	27.0	3.0050	16.5	.663	.636	2.368	1.182	.929	.0085	59.9	19.75		-4.10	15.65
719	1.2750	34.0	1.2835	340.0	.655	.630	2.357	1.181	.920	.0033	78.9	5.14		-.50	4.64
720	1.1730	20.5	2.7285	324.0	.655	.629	2.356	1.176	.922	.0062	80.6	12.29		-1.50	10.79

Table II. Effect of Input Deviations

Trial Individual 1% Deviations (By Approximate-Type Method)	Resulting Deviations in Angle of Unbalance					
	PA-26 (Low Residual Unbalance)		PA-11 (Med. Residual Unbalance)		PA-3 (High Residual Unbalance)	
	Deg.	%	Deg.	%	Deg.	%
Example Unbalance Condition (Degrees)	(5.43)		(12.11)		(23.31)	
A. 1% Deviation in Bomblet Weight	0	0	0	0	0	0
B. 1% Deviation in Bomblet Diameter	± .12	± 2.2	± .24	± 2.0	± .32	± 1.4
C. 1% Deviation in C.G. Distance	± .12	± 2.2	± .28	± 2.3	± .32	± 1.4
D. 1% Deviation in Axial Moment of Inertia (I_{xx})	±1.14	±21.0	±2.64	±21.8	± 5.82	±25.0
E. 1% Deviation in Transverse Moment of Inertia (I_{yy})	±1.87	±34.5	±4.58	±37.8	±15.80	±67.8
F. 1% Deviation in Transverse Moment of Inertia (I_{zz})	±1.87	±34.5	±4.58	±37.8	±15.80	±67.8
G. 1% Deviation in Left Plane Unbalance	± .09	± 1.7	± .13	± 1.1	± .12	± .5
H. 1% Deviation in Left Plane Unbalance Angle	± .23	± 4.2	± .10	± .8	± .05	± .2
I. 1% Deviation in Right Plane Unbalance	± .46	± 8.5	± .25	± 2.1	± .34	± 1.5
J. 1% Deviation in Right Plane Unbalance Angle	± .11	± 2.0	± .74	± 6.1	± .05	± .2

NOTE: A 1% deviation of items H and J is taken as 360/100 = 3.6 degrees.

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2. Material Test Procedure 4-2-801, APG, MD, Projectile Unbalance, 29 September 1965.

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